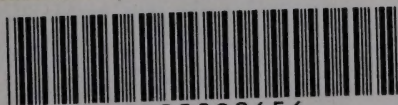


MOVEMENT OF THE HEART'S AXIS WITH RESPIRATION.

By THOMAS LEWIS.

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MOVEMENT OF THE HEART'S AXIS WITH RESPIRATION.

By THOMAS LEWIS.*

(Cardiac Department, University College Hospital Medical School.)

A FEW years ago, Einthoven, Fahr and Waart² described a method of calculating the electrical axis of the heart by means of electrocardiograms taken from the usual limb leads.

The electrical axis, as ascertained by them, corresponds to that line, in the plane of the leads, along which the greatest potential difference manifests itself. This line of greatest potential difference varies its position during different phases of the cardiac cycle, and may be calculated by the formulæ of these workers for any phase. It should be understood that the electrical axis does not correspond to the heart's anatomical axis, and is at the best but an indifferent guide to it; but it has been thought that the electrical axis may be used to determine *rotation* of the heart's anatomical axis, in that electrical and anatomical axis might be expected to bear a relatively constant inclination to each other. According to this view, if the anatomical axis rotates through a certain number of degrees as a result of mechanical displacement of the heart, the electrical axis for any particular phase of the heart's cycle should show a simultaneous and equal rotation. Such is the conclusion drawn on theoretical grounds in the article discussed.

A recent opportunity has occurred, which seems to make it possible to put this conclusion to the test.

S. T. C., a pensioner of 39 years, was discharged from the army in August, 1918. Having served for two years in the army he was incapacitated by a wound in the chest, on the 14th December, 1917. The bullet entered the chest at the left shoulder and remained deeply buried. He developed a left-sided hæmothorax, which was aspirated, and from which he recovered. An X-ray examination showed the bullet to be lodged in the heart, and his discharge from the army followed because he complained of shortness of

* Observations undertaken on behalf of the Medical Research Council.

breath, exhaustion, and some slight precordial distress on effort, dating from the time of his injury.

Examined on October the 23rd, 1919, he was found to be a spare though well built man. The heart's maximal impulse lay in the 5th rib interspace, well internal to the nipple line. The area of cardiac dulness was not increased. The heart sounds were natural, with the exception of an inconspicuous systolic murmur audible over the maximal impulse in the erect posture. The man presented no signs of heart failure, but by test exercises his breath was proved to be shorter than normal. The pulse, while the man stood at rest, showed an increase of rate (*viz.*, 100 to 120 per minute), and it increased further and readily upon effort.

The physical examination and review of his symptoms lent no support to the view that the presence of the bullet was responsible for his symptoms. No fault could be detected in the heart or circulation, other than those faults which are commonly manifested by patients who suffer from the symptoms summed up in the expressions "irritable heart of soldiers" or "effort syndrome." Repeated screenings of the chest demonstrated the following abnormalities. The movement of the left dome of the diaphragm, though considerable, was limited in its outermost part; it appeared to be a little adherent to the lateral wall of the chest, so that in descending it tended to become concave. Presumably the adherency was the sequel of the old hæmothorax on this side. The left side of the chest, however, was equally translucent with the right.

Viewed antero-posteriorly, a complete rifle bullet could readily be seen, lying vertically with its point uppermost; it lay in the silhouette of the heart, about $3\frac{1}{2}$ cms. to the right of the left margin of the ventricle and somewhat nearer the apex than the base of the ventricle. Viewed from the side, the bullet again presented itself in the heart's silhouette; it lay almost vertically, its point inclining a little towards the sternum, and somewhat nearer to the ventral than to the dorsal border of the heart. Its position relative to the chambers was judged from the antero-posterior, lateral and oblique positions; the bullet was thought to lie most probably embedded in the ventricular septum.

Viewed antero-posteriorly, the bullet showed an excursion of about 1 cm. towards the heart's apex during systole; at the same time its axis rotated in an anticlockwise fashion (the chief movement being at its base). Viewed in the lateral position the movements of the bullet with systole were slight.

Viewed both antero-posteriorly and laterally, the bullet was seen to rise approximately 2-3 cms., as the diaphragm moved from a position of deep inspiration to that of deep expiration. In the antero-posterior view its axis was seen to rotate with respiration, the movement being clockwise during inspiration and anticlockwise during expiration.

Rotation of the anatomical axis during respiration. Many attempts were made in October, 1919, to obtain an accurate measurement of the bullet's change of direction with respiration, in the hope of comparing these with the movement of the electrical axis, but these attempts were not completely successful. These earlier observations, nevertheless, have their value.

The patient came again under observation in February, 1923, and the attempts were successfully repeated. Meanwhile the patient had improved in health, being more robust and the heart rate normal. Examined under the X-ray (screening and skiagrams), the bullet was seen to occupy precisely the same position as before, and its movements with the heart beat and respiration were unaltered. Corresponding skiagrams taken during the first period are scarcely to be distinguished from those taken during the second period of observation. The bullet had evidently become permanently and rigidly fixed in the muscular wall of the ventricle.

Three methods of measuring the inclination of the bullet were used. (a) Screening the patient in the antero-posterior plane, the bullet being clearly visible and sharply defined. The preceding observations of the bullet's position and movements is equally applicable to these later observations. As previously stated, the base of the bullet moved during systole about 1 cm., or thereabout, towards the heart's apex, the point of the bullet remaining almost stationary or inclining a little towards the middle line. The movement was rather like that of a pendulum, being executed rapidly; the bullet hung for an appreciable time in the extreme position, corresponding to systole and diastole. The diastolic position appeared to be held the longer. By placing a flat ruler on the screen, its edge could be brought parallel to that of the missile in the diastolic position, and this procedure could be adopted in full inspiration and full expiration, and the inclinations ruled on the screen. So far as the diastole of the heart was concerned, this method was probably accurate within a few degrees. So far as systole was concerned it was found to be more precarious. (b) Instantaneous plates were repeatedly taken while the breath was held in the inspiratory and expiratory positions, the electrical contact being timed by the rhythm of the pulse. Although several helpful pictures were obtained, the method proved too uncertain. It was not possible subsequently to ascertain with certitude at what particular phase of systole and diastole the exposure had happened. (c). The most satisfactory method used was that of exposures of from 4 to 6 seconds, the tube lying 1 metre behind the patient's heart. In many of the plates so obtained, while the chest was fixed in either full inspiration or full expiration, the systolic and diastolic positions of the bullet were sufficiently clearly defined on the plate to allow its axes to be found with an error of not more than one or two degrees. A number of plates taken in this fashion have been compared and are in substantial agreement. The patient was an unusually intelligent man, and was at pains to maintain his posture and uniformly to repeat the inspiratory and expiratory movements.

Movement of the anatomical and electrical axis in the erect posture compared.

Anatomical axis. The patient stood in the erect posture, his sternum resting against the screen.

Method (a). Placing a ruler on the screen the inclination of the bullet in diastole was marked in the full inspiratory and expiratory positions of the chest. These two ruled lines met at an angle of 7.5° .

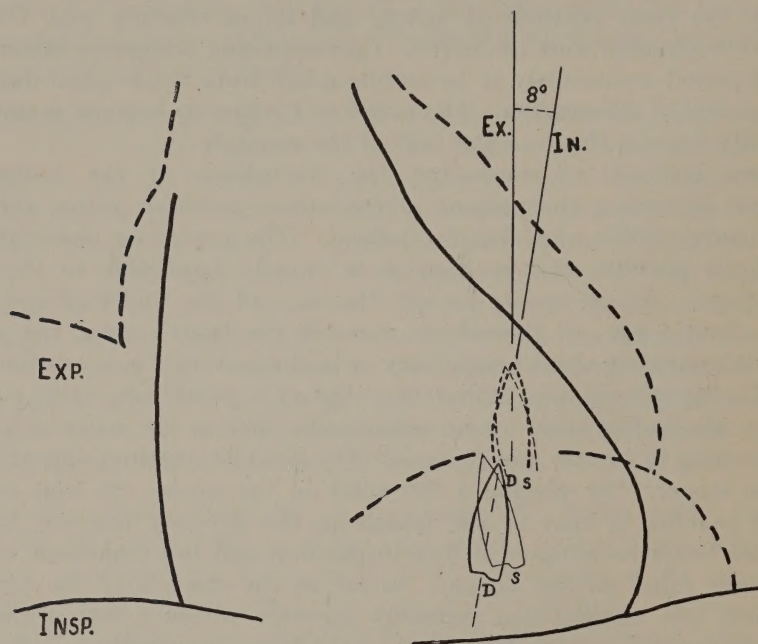


Fig. 1. Outlines of the heart and bullet (half natural size) in full inspiration and full expiration, traced from two X-ray plates taken from the patient in the erect posture. The X-ray tube was at 1 metre distance from the screen.

The unbroken outline represents inspiration and the broken outline expiration. The systolic (*S*) and diastolic (*D*) positions of the bullet are shown. The diastolic axis of the bullet moves anticlockwise through 8° in expiration.

Method (c). From two plates, each exposed for 4 seconds in the full inspiratory and expiratory positions, the superimposed tracings of Fig. 1 have been constructed. In this figure the inspiratory contours are represented by unbroken and the expiratory by broken lines. The diastolic position of the bullet (*D*) is represented by a heavy and the systolic position by a lighter outline. In full inspiration the bullet swung with each systole in an anticlockwise direction through 18° . During expiration it moved up through almost its length, and the swing with the heart beat was about

10°.* In the tracing (Fig. 1), two lines (inspiratory *IN.* and expiratory *EX.*) have been drawn through the axis of the bullet in diastole. They are inclined to each other at 8°. Thus, there is good agreement between the angle of movement in the photographs and the angle measured by ruling on the screen.

Electrical axis. Standard curves were now taken from leads, *I*, *II* and *III*, the patient standing and fixing the chest in full inspiration or

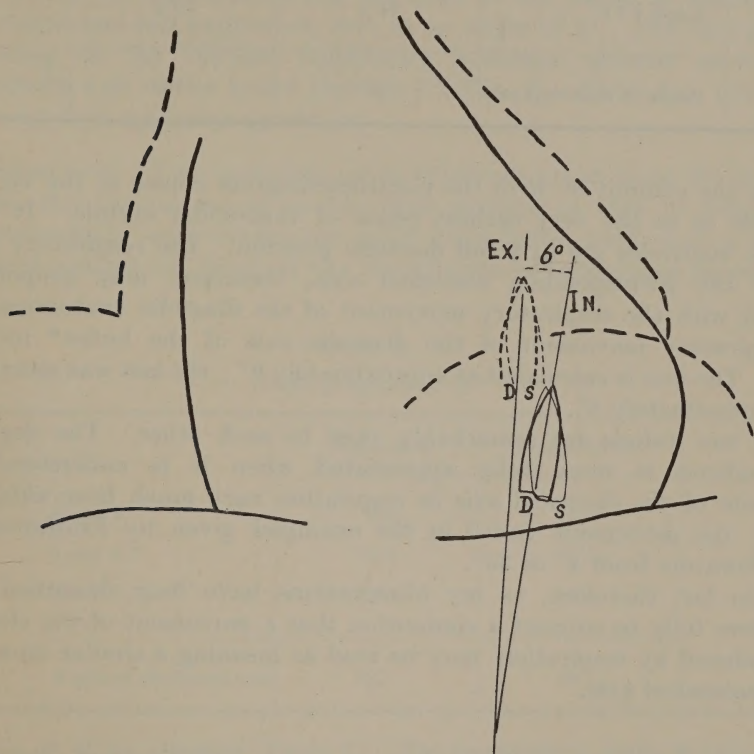


Fig. 2. Outlines of the heart and bullet constructed in the same fashion as Fig. 1. The patient was sitting when the plates were taken. The axis of the bullet moves anticlockwise through 6° in expiration.

expiration. Two complete series of such curves were in substantial agreement and the average values of the summit *R* are given in Table I. The electrical axis of the heart, corresponding to the time at which the summit of *R* was written, is calculated from these data to have been 85°† in inspiration and 76° in expiration. Thus, the electrical axis swung in expiration in an anticlockwise fashion through 9°.

* In some plates it was rather more than 10°.

† The axis passed from above downwards and to the left in the body with an inclination of 85° to the horizontal.

TABLE I.
Height of deflection "R."

			<i>Inspiration</i>	<i>Expiration.</i>
Lead I	..	..	1.5	3.5
Lead II	..	..	15.5	13.05
Lead III	..	..	14.0	10.0
Angle of electrical axis			85°	76°

Now the summit of *R* in the electrocardiogram comes at the very end of diastole or in the very earliest phase of ventricular systole. It occurs when the ventricles are in a full diastolic position. The respiratory movement of the corresponding electrical axis, therefore, may properly be compared with the respiratory movement of the diastolic anatomical axis. The respiratory movement of the diastolic axis of the bullet* indicates the last. The first is calculated at approximately 9°; the last was ascertained to be approximately 8°.

The two values are remarkably close to each other. The degree of correspondence is more fully appreciated when it is understood that movements of the electrical axis in respiration vary much from subject to subject; the movement varied in the examples given by Einthoven and his collaborators from 4° to 36°.

In so far, therefore, as my observations have been described, they would seem fully to support a contention that a movement of the electrical axis, produced by respiration, may be read as meaning a similar movement of the anatomical axis.

Movements of the anatomical and electrical axis in sitting posture compared.

To amplify these observations, a similar series was undertaken with the patient in a slightly different position, namely, while sitting upright in an easy position. This position was chosen after previous experience of the patient's electrocardiograms and their changes with respiration.

Anatomical axis. The movement of the right diaphragmatic dome of this patient was less in the sitting than in the standing posture; on the contrary, the movement of the left diaphragmatic dome was slightly greater. As a consequence, expiration moved the heart more towards the

* The axis of the bullet and a hypothetical anatomical axis of the ventricles will not necessarily correspond; but movement of the one should follow more or less accurately the movement of the other.

middle line in the sitting posture than in the standing. The upward excursion of the bullet in expiration was approximately the same in the two postures of the body; but, whereas in the erect posture the bullet moved a little away from the middle line, in the sitting posture it moved a little towards the middle line. During held inspiration the bullet swung anticlockwise through 13° at the systole; during held expiration it swung in a similar direction through 9° (see Fig. 2).

Lines ruled on the screen along the edge of the bullet at diastole, in full inspiration and full expiration, met at an angle of 8° . The two plates, corresponding to the extreme respiratory positions, showed movement of the diastolic axis of the bullet through 6° (Fig. 2). These two measurements are again in sufficient agreement.

Electrical axis. Two complete series of curves taken from the normal leads while the patient sat in an identical position to that in which the X-ray observations were made (the same stool being used, and a screen being placed against the front of the chest) were in substantial agreement.

TABLE II.
Height of deflection "R."

	<i>Inspiration</i>	<i>Expiration.</i>
Lead I	2.0	5.0
Lead II	14.5	11.50
Lead III	12.5	6.0
Angle of electrical axis	83°	63°

The values of *R* are given in Table II. The inspiratory angle is calculated at 83° and the expiratory at 63° , representing an anticlockwise movement of 20° in passing from the inspiratory to the expiratory positions; the anatomical axis, as gauged by the axis of the bullet, moved anticlockwise through 6° to 8° . This divergence is beyond the possible limits of error; it was, in fact, quite obvious on simple screening of the patient that the axis of the bullet changed through an angle of far less than 20° , the change was trifling in amount. The electrocardiograms taken in the same posture at a separate sitting gave an anticlockwise movement of 25° (83° to 58°).

To account for this divergence two possibilities suggest themselves. It is possible that the axis of the bullet changed its relation to the anatomical

axis of the heart as a result of change in the shape of the heart during respiration. It appears unlikely that a material change could be produced in this fashion, particularly so since the summit *R* is regarded to result from activity of the lower portions of the septal musculature and the adjoining parts of the ventricles,³ and the bullet lay in this region of the heart. To account for the divergence, therefore, a considerable movement of the bullet relative to the muscle immediately surrounding it must be supposed to have occurred during respiration; such an idea is opposed by the fixity of the bullet; its position had remained unaltered for several years. In a similar case reported by Bond, Phillips and Jevons¹, however, the axis of the bullet moved in a clockwise fashion during expiration, and through such a large angle that it is difficult to understand how the movement could have occurred unless enough leverage were exerted upon the bullet as materially to alter its position relative to the heart wall.

The alternative suggestion is that, in the antero-posterior plane, movements of the electrical axis do not necessarily convey an exact index of movements in the anatomical axis. That a movement of the heart's axis, through a certain angle in the antero-posterior plane, correspondingly influences the direction of the electrical axis by altering the relation of the potentials to the lie of the leads, is a conclusion which we may unhesitatingly accept; but that this is the only fashion in which respiration influences the electrical potentials is improbable. Some small change may result from altered heart rate (the inspiratory rate in this patient was approximately 73 and the expiratory rate 108 per minute); a further and perhaps larger change is certain to result if, during respiration, the heart rotates appreciably around its own axis.*

SUMMARY AND CONCLUSIONS.

1. In a patient in whom a rifle bullet had become fixed in the ventricle, observations have been undertaken upon the movements of this bullet during the heart beat and during respiration.
2. The bullet showed a pendulum-like swing with the heart beat, its base (the lower end) moving conspicuously towards the heart's apex in systole and receding from it in diastole.
3. During expiration the bullet moved almost vertically upwards; at the same time it altered its obliquity to the vertical, the movement being anticlockwise. This change in the bullet's obliquity has been

* Rotation around its axis should have been revealed by the relative positions of the small projection of the bullet at its base (see Fig. 6); unfortunately the shadow of the bullet's base was nearly always in part obscured by the raised dome of the diaphragm in expiration.

measured and the change of angle compared with that occurring in the electrical axis of the heart. The two changes were found to be identical in the erect position of the patient, but showed a conspicuous divergence while the patient sat.

4. It is thought to be improbable that movement of the electrical axis of the electrocardiogram resulting from respiration necessarily gauges accurately the movement of the heart's anatomical axis.

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